I.D. List of Relevant Publications

(1) B. Chandrasekaran, F. Gomez, S. Mittal and J. Smith, "An approach to medical diagnosis based on conceptual structures," Proc. International Joint Conference on AI, Tokyo, Japan, Aug. 1979.

(2) S. Mittal, B. Chandrasekaran and J. Smith, "Overview of MDX - a medical diagnosis system," Proc. III Annual Symposium on Computer Applications in Medical Care, Washington, D.C., October 1979.

(3) B. Chandrasekaran, S. Mittal and J. Smith, "RADEX - towards a computer-based radiology consultant," invited paper to appear in Pattern Recognition in Practice, Gelsema and Kanal, eds, North Holland, 1980 (exp).

(4) F. Gomez and B Chandrasekaran, "Knowledge organization and distribution for medical diagnosis," to appear in IEEE Trans SM&C.

(5) S. Mittal and B. Chandrasekaran, "Conceptual representation of patient databases," to appear in J. of Medical Systems.

(6) S. Mittal and B. Chandrasekaran, "Temporal Organization of events in a medical data base," to appear in Proc. Am. Conf. Cybernetics & Society, Boston, 1980.

I.E. Funding Support

1. Graduate Student Support: Jack Smith, M.D., is supported by NIH/NLM Biomedical Computer and Information Science Training Grant to the Ohio State University, Grant no. LM07023-02, total direct costs for the entire year of 79-80 is 87,959 (direct), but only a portion goes to support AIM Training for graduate students. The renewal proposal for this Training Grant has been approved by NLM, and we are awaiting funding.

2. NLM Research Support. A research proposal on "Conceptual Structures for Medical Knowledge Representation," B. Chandrasekaran, P.I., Application no. 1 R01 LM03500-01, submitted to the NLM Computers in Medicine Program has been approved by the Review Committee in its March, 80 meeting. We are awaiting funding. The approved level of funding is 80/81: 71,370, 81/82: 75,711 & 82/83: 80,111.

II. INTERACTIONS WITH THE SUMEX AIM RESOURCE

II.A. Medical Collaboration and program dissemination via SUMEX.

Most of our actual research is being conducted on the RUTGERS resource. We are aware that some researchers at Rutgers and elsewhere have studied the program in detail and exercised it. The ideas behind the program have thus been comprehended more concretely. In particular, several researchers at RUTGERS and our group have sat down at extended sessions in the TALK mode and have run our program, analyzed and critiqued it. Such an effort would be impossible without these resources.

II.B. Sharing and Interaction with other SUMEX-AIM Projects.

(1) Prof. Chandrasekaran participated in the Vermont NIH-AIM Workshop last year. This participation has been a major intellectual boost to our efforts.

(2) Prof. Chandrasekaran, Dr. Jack Smith and Sanjay Mittal will be attending the forthcoming NIH-AIM Workshop at Stanford in August 1980. They will be presenting a demonstration of the MDX system at the workshop.

(3) An important benefit of our use of the Rutgers LCSR system has been the availability of software like the Rutgers Lisp system, screen text editors, documentation preparation programs etc. Some of the programming language features we need for research into building experts-based systems will be provided in the new Lisp system under development at Rutgers. Our limited resources would have made it difficult to make such extensions to lisp.

(4) The mail facilities of SUMEX and RUTGERS resources are invaluable to us in exchanging ideas, and keeping track of AIM activities. There is simply no cost-effective substitute for the benefits of such communication for our research.

(5) There is a sense of cohesiveness and common purpose fostered by this resource. We have been able to make a number of professional contacts through the resource and engage in intellectual dialogs about problems of common interest in medical knowledge representation.

II.C. Critique of Resource Management.

The Rutgers facility which is our major computer is excellently managed and provides us adequate service. Our impression of the Stanford machine is similar, even though it is not based on as extensive a use.

The major weakness and source of anxiety for us is the unreliability and slowness of the TYMNET nodes. The unreliability of TYMNET has often created problems in continuous use of the SUMEX facilities. The very slow speed (currently only 300 baud) has been a major impediment in our research effort from the point of view of acceptable turnaround time. Anyone who has tried to use run editors like EMACS; run programs with lots of output; or print out large files, at 300 baud, would agree that it is a maddeningly slow process.

III. RESEARCH PLANS (8/80 - 7/86)

III.A. Project goals and plans.

A.i. Near-term (8/80 - 7/81)

(1) Expansion of the MDX system to larger domains of medicine, first to the whole of cholestasis, then to the domain of all liver diseases.

(2) Creation of facilities to understand and organize the temporal aspects of patient data and case histories.

(3) Implementation of MDX-II, embodying a more advanced problem-solving strategy, which will result in a more coherent unified diagnosis. This will be done for the domain of liver diseases.

A.ii. Long-term (8/81-7/86)

(1) Increasing the capabilities of MDX for consultation, including a) explanation of diagnosis, and b) ordering tests.

(2) Evaluation of MDX as a tool in a clinical environment.

(3) Extension of the RADEX system to store and retrieve imaging information over a much larger domain.

(4) Extension of conceptual patient data bases, and interpretive reporting facilities.

(5) "Learning" of new diagnostic information by the system. We would like to investigate how MDX can acquire new knowledge and skills, either from episodic information, or productive problem solving using underlying medical and commonsense knowledge structures.

(6) Use of MDX to evaluate the usefulness of particular symptoms, manifestations and data in the diagnostic process. This can currently be done only by a large expenditure of expert clinician time.

III.B. Justification and Requirements for Continued SUMEX Use.

I will talk more broadly of SUMEX/RUTGERS use.

a. Computing Facility: Our research will simply be crippled without it. AIM work of the kind that we do requires very good LISP support and a large machine. Our Department will shortly have a DEC20/20 which is altogether too small for the kind of work that we need to get done. Rutgers DEC20/50 has sufficient power for our immediate needs, even though there are problems about disc space even there. Of course both SUMEX and RUTGERS resources will probably need considerable enlargement if the number of users and the sizes of the projects grows, as they almost surely will.

b. Training Facility: We not only need access to these resources for research, but we need it for purposes of training graduate students in AIM issues. For instance most of the graduate students in our AIM activity as well as those associated with the NLM Biomedical Computing Training Grant can now get hands on experience with other AIM programs through our access to these resources. Thus as an educational tool in AIM, this resource is an essential one for our Training activity also. It should be emphasized that there are no viable alternatives to networking in this regard. AIM programs are large, experimental and need substantial supporting resources.

c. Community Building: We need to continue our interaction with the centers of AIM activity, as well as individual researchers such as Ruven Brooks at the University of Texas Medical Center (SUMEX-AIM user). We need to feel part of this common AIM purpose, otherwise research groups like ours which are very active but small would be rather isolated.

III.C. Needs and plans for other computing resources, beyond SUMEX-AIM

In the next five years, we anticipate a fairly substantial demand for computing resources for our research projects. Our anticipated requirements would be as follows:

1. Memory size - Within the next 2-3 years we would need a computer system which can provide program memory size of the order of 2M bytes or more. Unless DEC makes extensions to the Dec-10/Dec-20 architecture, we would have to explore alternate systems, such as the VAX or IBM 370.

2. Computer usage - Our usage of the computer system at the Rutgers LCSR has been steadily growing since we started using their system eight months back. However, it is not clear how much more we would be able to load their system in the next few years, without degrading the system performance substantially. Our own department at Ohio State is currently installing a new Dec 2020 system, which would help in providing additional computer resource for our research, though only in a limited way. We would be interested in exploring ways to upgrade this Dec2020 system with SUMEX support.

3. Disk storage - Our experience of last year has shown that development of knowledge-based systems in medicine require large amounts of secondary disk storage, for keeping different versions of source codes, compiled code, documentation etc. Currently we are using about 1500 pages (1 page= 2.5K bytes) on the Rutgers system. We expect this to increase by at least 100 percent in the next two years.

III.D. Recommendations for future community and resource development

Our experience in the past eight months as a member of the SUMEX community has been quite rewarding, both in terms of availability of computer and software resources, as well as contact with other researchers.

Our biggest source of frustration has been the slow communication access to the SUMEX computing systems. The Tymnet node at Columbus provides only a 300 baud line, which has proved to be a serious hindrance in our effective use of the Rutgers system. We would be very interested in exploring ways to upgrade this to at least 1200 baud, and if possible higher. Any help from SUMEX, both technical and financial would be very useful. We recommend that SUMEX explore ways to setup a nation wide network access to SUMEX computing systems, which provide the following:

a. High speed access to the SUMEX computing nodes.

b. File transfer capability between the SUMEX facilities and the local facilities of other members of the community.

The new technology in computer communications may enable the public carriers to be used for fashioning such a network.

We feel that the dissemination of ideas and software among different members of the AIM community may be enhanced by the introduction of a quarterly SUMEX newsletter. Such a newsletter could be used to announce new programs and utilities and provide a forum for discussion of work-in-progress and other ideas not yet ready for formal publication.

Appendix A

Community Growth and Project Synopses

This appendix contains a graphical display of the development of the SUMEX-AIM community over the years and brief synopses of currently active projects. Figure 6 below illustrates the substantial growth in the cumulative number of projects in the Stanford, national SUMEX, and Rutgers-AIM communities since the resource began operation in 1974.

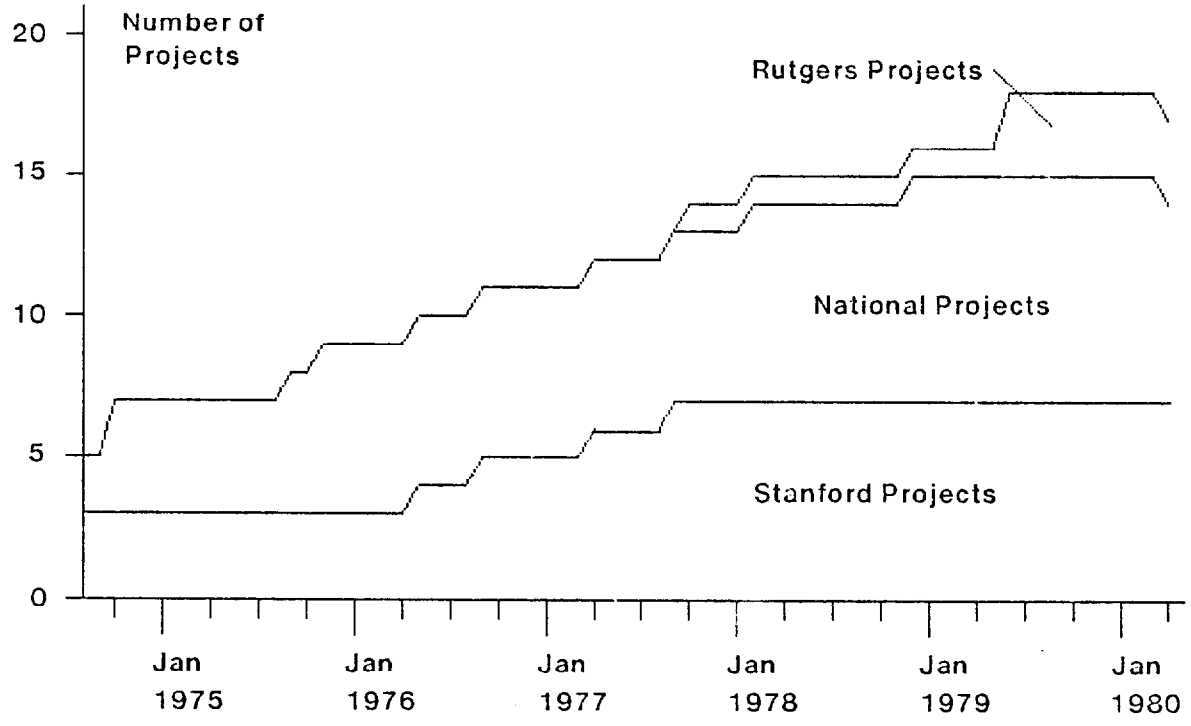

Figure 6. SUMEX-AIM Growth by Community

National AIM Project: ACQUISITION OF COGNITIVE PROCEDURES (ACT)

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The ACT Project combines a semantic network data-base with a production system to simulate human cognition. Prominent among the reasons for using a production system architecture as a framework for developing such a program is the possibility of modeling learning as the acquisition of new productions. ACT possesses a number of learning mechanisms which have been used to model the learning of procedural skills such as language comprehension and geometry theorem proving. Some of these mechanisms have the effect of either extending or restricting the set of circumstances in which a particular behavior is performed so as to produce better performance. Others have the effect of speeding up cognitive operations by compressing the effects of a series of production applications into the application of a single production. Out of this set of productions ACT applies those that usually result in desirable outcomes. In this way it is able to model the human ability to learn even when given unreliable feedback. Another feature of ACT that reflects its psychological orientation is its willingness to model human limitations. Here the hope is that by being faithful to the human mind even in its failings, it eventually may be possible to emulate its successes.

SOFTWARE AVAILABLE ON SUMEX

The ACT production system is available to GUEST users of SUMEX.

REFERENCES

Anderson, J.R.: Language, Memory, and Thought. Lawrence Erlbaum Associates, Hillsdale, N.J., 1976.

Anderson, J.R., Kline, P.J. and Lewis, C.H.: A production system model of language processing. IN M.A. Just and P.A. Carpenter (eds.), Cognitive Processes in Comprehension. Lawrence Erlbaum Associates, Hillsdale, N.J., 1977.

Anderson, J.R. and Kline, P.J.: A learning system and its psychological implications. Proc. Sixth IJCAI, Tokyo, August, 1979.

National AIM Project: SIMULATION AND EVALUATION OF CHEMICAL SYNTHESIS (SECS)

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The SECS Project aims at developing practical computer programs to assist investigators in designing syntheses of complex organic molecules of biological interest. Key features of this research include the use of computer graphics to allow chemist and computer to work efficiently as a team, the development of knowledge bases of chemical reactions, and the formation of plans to reduce the search for solutions. SECS is being used by the pharmaceutical industry for designing syntheses of drugs.

A spin-off project, XENO, is aimed at predicting the plausible metabolites of foreign compounds for carcinogenicity studies. First, the metabolism is simulated; then the metabolites are evaluated for possible carcinogenicity.

SOFTWARE AVAILABLE ON SUMEX

SECS-- Available with a reaction library of over 400 reactions. The user needs a TTY or a DEC GT40 type graphics terminal.

XENO-- (for prediction of metabolites of xenobiotic compounds) is available for preliminary exploration since the project is still in the early development stages.

PRXBLD--(for building approximate molecular models from two-dimensional molecular models) is an energy minimization approach which is available both stand-alone and included within SECS.

REFERENCES

Spann, M.L., Chu, K.C., Wipke, W.T. and Ouchi, G.: Use of computerized methods to predict metabolic pathways and metabolites. J. Env. Pathology and Toxicology 2:123, 1978.

Wipke, W.T., Smith, G., Choplin, F. and Sieber, W.: SECS--Simulation and Evaluation of Chemical Synthesis: Strategy and planning. IN Computer-assisted Organic Synthesis Planning. ACS Symposium Series, 1977, pp. 97-127.

Wipke, W.T., Ouchi, G. and Krishnan, S.: Simulation and Evaluation of Chemical Synthesis--SECS. An application of artificial intelligence techniques. Artificial Intelligence 10:999, 1978.

Rutgers AIM Project: A CLINICAL DECISION-MAKING MODEL INCORPORATING GOAL-SEEKING AND FOCUSING STRATEGIES

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Clinical decision-making in the model is viewed as a process which involves: 1) formulation of a set of diagnostic hypotheses and estimation of their likelihoods; 2) posing of patient management goals appropriate to the diagnostic hypotheses; and 3) selection of tests to perform, based on the relationship between the likelihoods of diagnosis and the certainty levels, or threshold probabilities, required for adoption of corresponding management goals. Focusing on particular diagnoses is accomplished by requiring minimum certainty levels for consideration of the diagnostic hypotheses. Probabilities are revised by Bayesian methods. The choice among suitable tests involves a heuristic scoring process. The system is being applied initially to the evaluation of upper abdominal pain.

SOFTWARE AVAILABLE ON SUMEX

Programs are in a developmental stage on the RUTGERS-AIM system and not yet available for use.

REFERENCES

Greenes, R.A.: Investigations in clinical decision-making. NLM program project grant application 1 P01 LM03401-01, 1979, pp. B27-31.

Greenes, R.A.: A goal-directed method for investigation of thresholds for medical action. Proc. Third Annual Symposium Computer Applications in Medical Care, Washington, D.C., 1979, pp. 47-51.

National AIM Project: HIERARCHICAL MODELS OF HUMAN COGNITION

Principal Investigators: Walter Kintsch, Ph.D. (KINTSCH@SUMEX-AIM)
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The CLIPR Project is concerned with the modeling of complex psychological processes. It is comprised of two research groups. The prose comprehension group has completed a project that carries out the microstructure text analysis described by Miller and Kintsch (1980), yielding predictions of the recall and readability of that text by human subjects. More recently, this group has been interacting with the Heuristic Programming Project at Stanford, using the AGE and UNITS packages to build a more complex model of the knowledge-based processes characteristic of prose comprehension. The planning group is working toward a model of the planning processes used by expert computer software designers. The initial development of this model requires the detailed analysis of expert software design protocols for subsequent simulation.

SOFTWARE AVAILABLE ON SUMEX

A set of programs has been developed to perform the microstructure text analysis described in Kintsch and van Dijk (Psychological Review, 1978) and Miller and Kintsch (1980). The program accepts a propositionalized text as input, and produces estimates of the text's recall and readability.

REFERENCES

Atwood, M.E., Polson, P.G., Jeffries, R. and Ramsey, H.R.: Planning as a process of synthesis. Technical Report SAI-78-144-DEN. Science Applications, Inc., Denver, Colorado, December, 1978.

Kintsch, W.: On modeling comprehension. Educ. Psychologist, 14:3-14, 1979.

Miller, J.R. and Kintsch, W.: Readability and recall of short prose passages: A theoretical analysis. J. Experimental Psychology: Human Learning and Memory, 1980. (In press)

National AIM Project: HIGHER MENTAL FUNCTIONS (HMF)

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The HMF Project contributes new knowledge and instruments to the fields of psychiatry and neurology using concepts and techniques of artificial intelligence. The research includes a model of paranoid behavior, a cognitive psychiatric taxonomy, and the development of intelligent speech prostheses for nonspeaking patients.

SOFTWARE AVAILABLE ON SUMEX

PARRY--An interactive program which can be interviewed in unrestricted natural language and responds linguistically the way paranoid patients respond in an initial psychiatric interview.

REFERENCES

Colby, K.M.: Mind models: An overview of current work. Mathematical Biosciences 39:159-185, 1978.

Colby, K.M., Christinaz, D. and Graham, S.: A computer-driven personal, portable and intelligent speech prosthesis. Computers and Biomedical Research 11:337-343, 1978.

Colby, K.M.: Computer simulation and artificial intelligence in psychiatry. IN E.A. Serafetinedes (ed.), Methods of Biobehavioral Research. Grune and Stratton, New York, 1979.

National AIM Project: INTERNIST

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The major goal of the INTERNIST Project is to produce a reliable and adequately complete diagnostic consultative program in the field of internal medicine. Although this program is intended primarily to aid skilled internists in complicated medical problems, the program may have spin-off as a diagnostic and triage aid to physicians' assistants, rural health clinics, military medicine and space travel. In the design of INTERNIST we have attempted to model the creative, problem-formulation aspect of the clinical reasoning process. The program employs a novel heuristic procedure that composes differential diagnoses, dynamically, on the basis of clinical evidence. During the course of an INTERNIST consultation, it is not uncommon for a number of such conjectured problem foci to be proposed and investigated, with occasional major shifts taking place in the program's conceptualization of the task at hand.

SOFTWARE AVAILABLE ON SUMEX

Versions of INTERNIST are available for experimental use, but the project continues to be oriented primarily towards research and development; hence, a stable production version of the system is not yet available for general use.

REFERENCES

Pople, H.E., Myers, J.D. and Miller, R.A.: The DIALOG model of diagnostic logic and its use in internal medicine. Proc. Fourth IJCAI, Tbilisi, USSR, September, 1975.

Pople, H.E.: The formation of composite hypotheses in diagnostic problem solving: An exercise in synthetic reasoning. Proc. Fifth IJCAI, Boston, August, 1977.

National AIM Project: BIOMEDICAL KNOWLEDGE ENGINEERING IN CLINICAL MEDICINE (PUFF/VM)

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The PUFF/VM Project has produced two knowledge-based programs for the interpretation of physiologic measurements made in clinical medicine. The interpretations are intended to aid in diagnostic decision-making and in selecting therapeutic actions. The programs are: PUFF--the evaluation of pulmonary function laboratory data, and VM--the evaluation and management of respiratory status for patients in the intensive care unit.

The task of the PUFF PROGRAM is to interpret standard measures of pulmonary function. In the laboratory at the Pacific Medical Center (PMC), about 50 parameters are calculated from measurement of lung volumes, flow rates, and diffusion capacity. In addition to these measurements, patient history and referral diagnosis also are used to interpret the test results. PUFF produces a report for the patient record, explaining the clinical significance of measured test results. It also provides a diagnosis of the presence and severity of pulmonary disease. The interpretation process is accomplished by examination of expert knowledge represented by a set of production rules. Each rule relates physiologic measurements or states to a conclusion about the physiologic significance of the measurement or state. A version of the PUFF program is used daily at the PMC.

The VENTILATOR MANAGER (VM) PROGRAM is designed to interpret on-line physiologic data in the intensive care unit (ICU). These data are used to manage post-surgical patients receiving mechanical assistance in breathing. VM is an extension of a physiologic monitoring system, and is designed to perform 5 specialized tasks in the ICU: 1) to detect possible measurement errors; 2) to recognize untoward events in the patient/machine system and suggest corrective action; 3) to summarize the patient's physiologic status; 4) to suggest adjustments to therapy based on the patient's status over time, and long-term therapeutic goals; and 5) to maintain a set of patient-specific expectations and goals for future evaluation by the program. The program produces interpretations of the physiologic measurements over time, using a model of the therapeutic procedures in the ICU and clinical knowledge about the diagnostic implications of the data.

SOFTWARE AVAILABLE ON SUMEX

The PUFF and VM programs will be available to GUEST users for use on pre-existing (non-identifiable) cases. No packages currently exist for program development.

REFERENCES

Fagan, L.M., Kunz, J.C., Feigenbaum, E.A. and Osborn, J.J.: A symbolic processing approach to measurement interpretation in the intensive care unit. Proc. Third Annual Symposium Computer Applications in Medical Care, Silver Spring, Maryland, October, 1979, pp. 30-33.

Fagan, L.M., Shortliffe, E.H. and Buchanan, B.G.: Computer-based medical decision making: From MYCIN to VM. Automedica 3(2), 1980.

Kunz, J.C., Fallat, R.J., McClung, D.H., et al: A physiological rule based system for interpreting pulmonary function test results. Heuristic Programming Project Report HPP-78-164, Computer Science Dept., Stanford Univ., November, 1978.

Osborn, J.J., Fagan, L.M., Fallat, R.J., et al: Managing the data from respiratory measurements. Med. Instrumentation, November-December, 1979.

Rutgers AIM Project: RUTGERS RESEARCH RESOURCE - COMPUTERS IN BIOMEDICINE

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The broad objective of the Resource is to apply advanced methods in computer science, particularly in artificial intelligence (AI), to biomedical problems. The Resource has three major areas of study: 1) Medical Modeling and Decision Making in several medical domains with emphasis on collaborative development of consultation systems in rheumatology and ophthalmology; 2) Modeling of Belief Systems and Commonsense Reasoning with emphasis on the psychology of plan recognition and handling of stereotypes; and 3) Artificial Intelligence studies with emphasis on Representations, Interpretation processes, and problems of knowledge and expertise acquisition. The studies in Medical Modeling and Decision Making are performed jointly by computer and medical scientists at Rutgers and elsewhere in the Country and abroad.

The Resource also sponsors national Artificial Intelligence in Medicine (AIM) Workshops for the AIM community.

SOFTWARE AVAILABLE ON SUMEX

CASNET--System for consultation in the diagnosis and treatment of glaucoma.

EXPERT--System for designing and applying consultation models using a relatively simple language to describe the models.

REFERENCES

Amarel, S.: Computer-based interpretation and modeling in medicine and psychology: The Rutgers Research Resource. IN Siler and Lindberg (eds.), Computers in Life Science Research. Foseb and Planum, 1975.

Schmidt, C.F., Sridharan, N.S., and Goodson, J.L.: The plan recognition problem: An intersection of psychology and artificial intelligence. AI Journal 11(1,2), August, 1978 (special issue on applications to the sciences and medicine).

Weiss, S., Kulikowski, C.A., Amarel, S. and Safir, A.: A model-based method for computer-aided medical decision-making. AI Journal 11(1,2), August, 1978 (special issue on applications to the sciences and medicine).

National AIM Project: SIMULATION OF COGNITIVE PROCESSES (SCP)

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The general purpose of the SCP Project is to develop increased understanding of normal and deficient cognitive functions, especially in reading and mathematics. Earlier work included simulations of interactive processes of grapheme-phoneme decoding and word recognition, and of semantic processes in comprehension of quantitative information in arithmetic word problems. The main emphasis at this time is on a collaboration with John Anderson, using the ACTF system to explore mechanisms of learning in the domain of geometry proofs. The SCP part of this work includes development of a system that learns by reading example proofs. The goal is to identify conceptual structures that are required for a learner to acquire planning strategies.

SOFTWARE AVAILABLE ON SUMEX

Programs are in a developmental stage and not yet available for use.

REFERENCES

Greeno, J.G., Magone, M.E. and Chaiklin, S.: Theory of constructions and set in problem solving. IN Memory and Cognition (In press). (Also available as Technical Report 1979/9, Learning Research and Development Center, Univ. Pittsburgh.)

Greeno, J.G.: Preliminary steps toward a cognitive model of learning primary mathematics. IN K. Fuson and W. Geeslin (eds.), Models of Children's Mathematical Learning, ERIC Information Center. (In press)

Lesgold, A.M. and Curtis, M.E.: Learning to read words efficiently. IN A. Lesgold and C. Perfetti (eds.), Interactive Processes in Reading, Erlbaum, Hillsdale, N.J. (In progress)

Stanford Project: GENERALIZATION OF AI TOOLS (AGE)

Principal Investigators: H. Penny Nii (NII@SUMEX-AIM)
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The long-range objective of AGE, a SUMEX CORE RESEARCH Project, is to build a software laboratory for building knowledge-based, application programs. It is an attempt to define and accumulate knowledge-engineering tools, with rules to guide in the use of these tools. The design and implementation of the AGE program will be based primarily on the experiences gained in building knowledge-based programs by the Stanford Heuristic Programming Project in the last decade (The programs that have been or are being built are: DENDRAL, META-DENDRAL, MYCIN, HASP, AM, MOLGEN, GUIDON, CRYSALIS, PUFF, VM and SACON.). The initial AGE program contains a collection of tools suitable for constructing user programs based on the Blackboard paradigm (used in HASP and CRYSALIS). In addition, AGE has facilities to aid the user in the construction, debugging, and running of his program.

SOFTWARE AVAILABLE ON SUMEX

AGE-1 is available on an experimental basis to a limited number of users. A public version of the programs, together with reference manuals and user guides, is planned for July, 1980.

REFERENCES

Nii, H.P. and Feigenbaum, E.A.: Rule-based understanding of signals. IN D.A. Waterman and F. Hayes-Roth (eds.), Pattern-directed Inference Systems. Academic Press, 1978, pp. 483-501.

Nii, H.P. and Aiello, N.: AGE: A knowledge-based program for building knowledge-based programs. Proc. Sixth IJCAI, Tokyo, August, 1979, pp. 645-655.

Stanford Project: HANDBOOK OF ARTIFICIAL INTELLIGENCE

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The AI Handbook Project is a part of SUMEX CORE RESEARCH aimed at making the important results of AI research accessible to the large, multi-disciplinary community of scientists who want to build AI systems in their own problem areas. Students and researchers at Stanford and other AI laboratories have prepared over 300 short articles describing the fundamental ideas, useful techniques, and exemplary programs developed in the field over the last 20 years. These articles have been written for computer-literate scientists and engineers in other fields who are unfamiliar with AI research and jargon. The Handbook will provide a scientist who, for instance, might want to know what a "heuristic" is or how to build a "natural language" front end, with information about all of the relevant AI techniques and existing systems, as well as abundant pointers into the field's literature.

The Handbook is being published in report and book form. It also will be made available to the SUMEX community via an on-line information retrieval system. Following is a TOPIC OUTLINE for Volumes I and II: HANDBOOK OF ARTIFICIAL INTELLIGENCE

INTRODUCTION: The Handbook of Artificial Intelligence; Overview of AI Research; History of AI; An Introduction to the AI Literature

SEARCH: Overview; Problem Representation; Search Methods for State Spaces, AND/OR Graphs, and Game Trees; Six Important Search Programs

REPRESENTATION OF KNOWLEDGE: Issues and Problems in Representation Theory; Survey of Representation Techniques; Seven Important Representation Schemes;

AI PROGRAMMING LANGUAGES: Historical Overview of AI Programming Languages; Comparison of Data Structures and Control Mechanisms in AI Languages; LISP

NATURAL LANGUAGE UNDERSTANDING: Overview - History and Issues; Grammars; Parsing Techniques; Text Generation Systems; Machine Translation; The Early NL Systems; Six Important Natural Language Processing Systems

SPEECH UNDERSTANDING SYSTEMS: Overview - History and Design Issues; Seven Major Speech Understanding Projects

APPLICATIONS-ORIENTED AI RESEARCH--SCIENCE AND MATHEMATICS: Overview; TEIRESIAS - Issues in Expert Systems Design; Research on AI Applications in Mathematics (MACSYMA and AM); Research on AI Applications in Chemistry (DENDRAL, CRYSALIS, etc.); Other Scientific Applications Research

APPLICATIONS-ORIENTED AI RESEARCH--MEDICINE: Overview of Medical Applications Research; Six Important Medical Systems

APPLICATIONS-ORIENTED AI RESEARCH--EDUCATION: Historical Overview of AI Research in Educational Applications; Issues and Components of Intelligent CAI Systems; Seven Important ICAI Systems

AUTOMATIC PROGRAMMING: Overview; Techniques for Program Specification; Approaches to AP; Eight Important AP Systems

The following sections of the Handbook are still in preparation and will appear in Volume III: Theorem Proving; Vision; Robotics; Information Processing Psychology; Learning and Inductive Inference; Planning and Related Problem-solving Techniques.

Stanford Project: DENDRAL--RESOURCE RELATED RESEARCH - COMPUTERS IN CHEMISTRY

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The DENDRAL Project involves research in computer-assisted structure elucidation of unknown organic compounds of biological importance. This research has three major components: 1) program development; 2) biochemical applications; and 3) resource-sharing.

Recent program developments have been directed toward building more powerful interactive programs to assist chemists in the three major areas of structure elucidation: analysis of data to yield substructural information about an unknown ("planning"), advanced methods for assembly of substructures into complete structures ("structure generation"), and the prediction of data for structural candidates to rank-order the candidates by comparison of predicted and observed data ("testing"). Important problems of structure representation have been solved which have enabled dealing with stereochemical (three-dimensional) aspects of structure throughout the procedures.

Major areas of application of the programs in the research of this group and other collaborative projects include: a) marine natural products, particularly marine steroids and halogenated compounds which display biological activity; b) antibiotics and other derivatives of known or potential drugs; c) terpene alkaloids; d) photoproducts related to vitamin A; and e) conformational studies of narcotic analogs and polypeptides.

These programs are shared among a community of collaborators and guest users at SUMEX, with communication via computer network from a variety of sites in the U.S., Europe and Australia. Exportable versions of some programs are maintained. These versions have been installed successfully in more than 10 research laboratories throughout the world.

SOFTWARE AVAILABLE ON SUMEX

CONGEN--An interactive program for structure generation to yield candidate structures for an unknown based on inferred substructural components (exportable).

GENOA--An advanced structure generator capable of handling overlapping substructural information; uses CONGEN as a core component (exportable).

Meta-DENDRAL--An INTSUM, RULEGEN and RULEMOD sequence for automatic rule formation to relate observed data to substructures in mass spectrometry and carbon magnetic resonance spectroscopy.

REACT--A program for carrying out a complex sequence of chemical reactions and exploration of the consequences of those reactions.

NMR--For substructural inference and spectrum prediction in carbon magnetic resonance spectroscopy (will be exportable).

REFERENCES

Carhart, R.E., Varkony, T.H. and Smith, D.H.: Computer assistance for the structural chemist, IN D.H. Smith (ed.), Computer-Assisted Structure Elucidation. American Chemical Society, Washington, D.C., 1977, p. 126.

Djerassi, C., Smith, D.H. and Varkony, T.: A novel role of computers in the natural products field. Naturwiss. 66:9, 1979.

Nourse, J.G., Carhart, R.E., Smith, D.H. and Djerassi, C.: Exhaustive generation of stereoisomers for structure elucidation. J. Am. Chem. Soc. 101:1216, 1979.

Stanford Project: MOLGEN--AN EXPERIMENT PLANNING SYSTEM FOR MOLECULAR GENETICS

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The goal of the MOLGEN Project is to apply the techniques of artificial intelligence to the domain of molecular biology with the aim of providing assistance to the experimental scientist. The most substantial problem under consideration is the task of experiment design. Two major approaches to this problem have been explored, one which instantiates abstracted experimental strategies with specific laboratory tools, and one which creates plans in toto, heavily influenced by the role played by interactions between plan steps. As part of the effort to build an experiment design system, a knowledge representation and acquisition package--the UNITS System, has been constructed. A large knowledge base, containing information about nucleic acid structures, laboratory techniques, and experiment-design strategies, has been developed using this tool. Smaller systems, such as programs which analyze primary sequence data for homologies and symmetries, have been built when needed.

SOFTWARE AVAILABLE ON SUMEX

Knowledge-based Experiment Design system (Friedland).

Meta-planning with Constraints experiment design system (Stefik).

UNITS system for knowledge representation and acquisition.

Interactive KORN Program for DNA sequence analysis.

GA1 program for restriction map construction.

SAFE program for gene excision.

REFERENCES

Friedland, P.E.: Knowledge-based experiment design in molecular genetics (Ph.D. thesis). Computer Science Dept. Report, CS-79-771, Stanford Univ.

Friedland, P.E.: Knowledge-based experiment design in molecular genetics. Proc. Sixth IJCAI, Tokyo, August, 1979, pp. 285-287.

Stefik, M.J.: An examination of a frame-structured representation system. Proc. Sixth IJCAI, Tokyo, August, 1979, pp. 845-852.

Stefik, M.J.: Planning with constraints (Ph.D. thesis). Computer Science Dept. Report, Stanford Univ. (In progress)

Stanford Project: MYCIN--KNOWLEDGE ENGINEERING FOR MEDICAL CONSULTATION

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EMYCIN: Dr. Buchanan, and William van Melle
GUIDON: Drs. Buchanan, and William J. Clancey
ONCOCIN: Dr. Shortliffe, and A. Carlisle Scott

The MYCIN Project is a collaborative group of physicians and computer scientists who are developing intelligent systems using the techniques of knowledge engineering. The research focus includes knowledge acquisition, inexact reasoning, explanation, education, and the representation of time and of expert thinking patterns. Project members currently are working in a variety of medical domains including infectious disease therapy selection, intelligent computer-aided instruction, and the management of cancer chemotherapy protocols. Recent emphasis in the research has included intensive work regarding human engineering, in an effort to implement the cancer therapy system for physicians to use in the near future. There is also a heightened interest in gearing representation, knowledge acquisition, and explanation more to the way that an expert actually thinks.

SOFTWARE AVAILABLE ON SUMEX

MYCIN--A consultation system designed to assist physicians with the selection of antimicrobial therapy for severe infections. It has achieved expert level performance in formal evaluations of its ability to select therapy for bacteremia and meningitis. The program continues to provide a powerful research environment for developing new approaches to the basic questions involved in knowledge engineering.

EMYCIN--The "essential MYCIN" system is a generalization of the MYCIN knowledge representation and control structure. It is designed to facilitate the development of new expert consultation systems for both clinical and non-medical domains.

GUIDON--A system developed for intelligent computer-aided instruction. Although it is being developed in the context of MYCIN's infectious

disease knowledge base, the techniques are generalizable to any EMYCIN domain. The current research emphasis has been on an improved understanding of how the expert thinks so as to optimize the learning experience for the student.

ONCOCIN--This newest subproject is a system designed to assist oncologists with the management of cancer chemotherapy protocols. Because the knowledge in this domain is already well-specified, the research emphasis is on human engineering and achieving clinical acceptance of the program.

REFERENCES

Clancey, W.J., Shortliffe, E.H. and Buchanan, B.G.: Intelligent computer-aided instruction for medical diagnosis. Proc. Third Conference Computer Applications in Medical Care, Silver Spring, Maryland, October, 1979, pp. 175-183.

Shortliffe, E.H., Buchanan, B.G. and Feigenbaum, E.A.: Knowledge engineering for medical decision making: A review of computer-based clinical decision aids. Proc. IEEE 67:1207-1224, 1979.

van Melle, W.: A domain-independent production rule system for consultation programs. Proc. Sixth IJCAI, Tokyo, August, 1979, pp. 923-925.

Yu, V.L., Fagan, L.M., Wraith, S.M., et al: Antimicrobial selection by a computer - A blinded evaluation by infectious disease experts. JAMA 242:1279-1282, 1979.